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James Clerk Maxwell Prize for Plasma Physics: The Physics of Magnetic Reconnection and Associated Particle Acceleration

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Solar and stellar flares, substorms in the Earth's magnetosphere, and disruptions in laboratory fusion experiments are driven by the explosive release of magnetic energy through the process of magnetic reconnection. During reconnection oppositely directed magnetic fields break and cross-connect. The resulting magnetic slingshots convert magnetic energy into high velocity flows, thermal energy and energetic particles. A major scientific challenge has been the multi-scale nature of the problem: a narrow boundary layer, "the dissipation region," breaks field lines and controls the release of energy in a macroscale system. Significant progress has been made on fundamental questions such as how magnetic energy is released so quickly and why the release occurs as an explosion. At the small spatial scales of the dissipation region the motion of electrons and ions decouples, the MHD description breaks down and whistler and kinetic Alfven dynamics drives reconnection. The dispersive property of these waves leads to fast reconnection, insensitive to system size and weakly dependent on dissipation, consistent with observations. The evidence for these waves during reconnection in the magnetosphere and the laboratory is compelling. The role of turbulence within the dissipation region in the form of "secondary islands" or as a source of anomalous resistivity continues to be explored. A large fraction of the magnetic energy released during reconnection appears in the form of energetic electrons and protons – up to 50% or more during solar flares. The mechanism for energetic particle production during magnetic reconnection has remained a mystery. Models based on reconnection at a single large x-line are incapable of producing the large numbers of energetic electrons seen in observations. Scenarios based on particle acceleration in a multi-x-line environment are more promising. In such models a link between the energy gain of electrons and the magnetic energy released, a requirement to explain the observations, has been established. The talk will review key observational data and emphasize basic physical principles to introduce the topic to the non-specialist.

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